FISHERIES AGENCY, MINISTRY OF AGRICULTURE AND FORESTRY
TOKAI REGIONAL FISHERIES RESEARCH LABORATORY
ICHITARO GENSHO, DIRECTOR

SPECIAL PUBLICATION No. 3

1. A REPORT ON OCEANOGRAPHICAL INVESTIGATIONS IN THE SALMON FISHING GROUNDS OF THE NORTH PACIFIC, 1952 AND 1953

BY

NOBUO WATANABE

2. A PRELIMINARY REPORT ON SURVEYS OF PLANKTON AND SALMON STOMACH CONTENTS FROM THE NORTH PACIFIC, 1952

BY

ZINZIRO NAKAI
AND
KOJI HONJO

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EDITORIAL NOTE

This series is intended to include those papers which have been submitted to international scientific meetings and are deemed to be adequate for further circulation. Reports in preliminary stages will also be published in this form from time to time for the purpose of throwing the high light upon some of important works requiring immediate dissmination.

TOKAI REGIONAL FISHERIES RESEARCH LABORATORY
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1. A REPORT ON OCEANOGRAPHICAL INVESTIGATIONS IN THE SALMON FISHING GROUNDS OF THE NORTH PACIFIC, 1952 AND 1953

Nobuo Watanabe*

Numbers of data have been obtained from the oceanographical investigations conducted by the R. V. "Tenyo-Maru" in the North Pacific during the salmon fishing season of 1952 and 1953 (see Figure for stations occupied and items of observations). Analyses of the data are making progress by comparing them with the previous observations 1/ carried out by oceanographers of Japan, the United States and U.S.S.R.

On the basis of these studies important findings are summarized here in the form of a preliminary report.

1) *Annual Recurrence of Oceanographical Patterns:*

Nothing has been known about oceanographical conditions of the North Pacific under study for the seasons of winter and early spring because there has been no data available for this region of the sea in these particular times of the year. However, as a result of the recent investigations, oceanographical information of the area for the seasons from spring to early fall could be supplemented to some extent. The following are typical oceanographical changes that seem to be in recurrence over the area every year as far as our data are concerned.

During the spring there is in the upper layer of this region a boundary line formed by the subarctic surface cold water and warm water from the temperate zone, i.e., a polar front extending eastward approximately in parallel of lat. 40°N. When the season goes on, the northward movement of warm water pushes the subarctic cold water back to the north and northwest.

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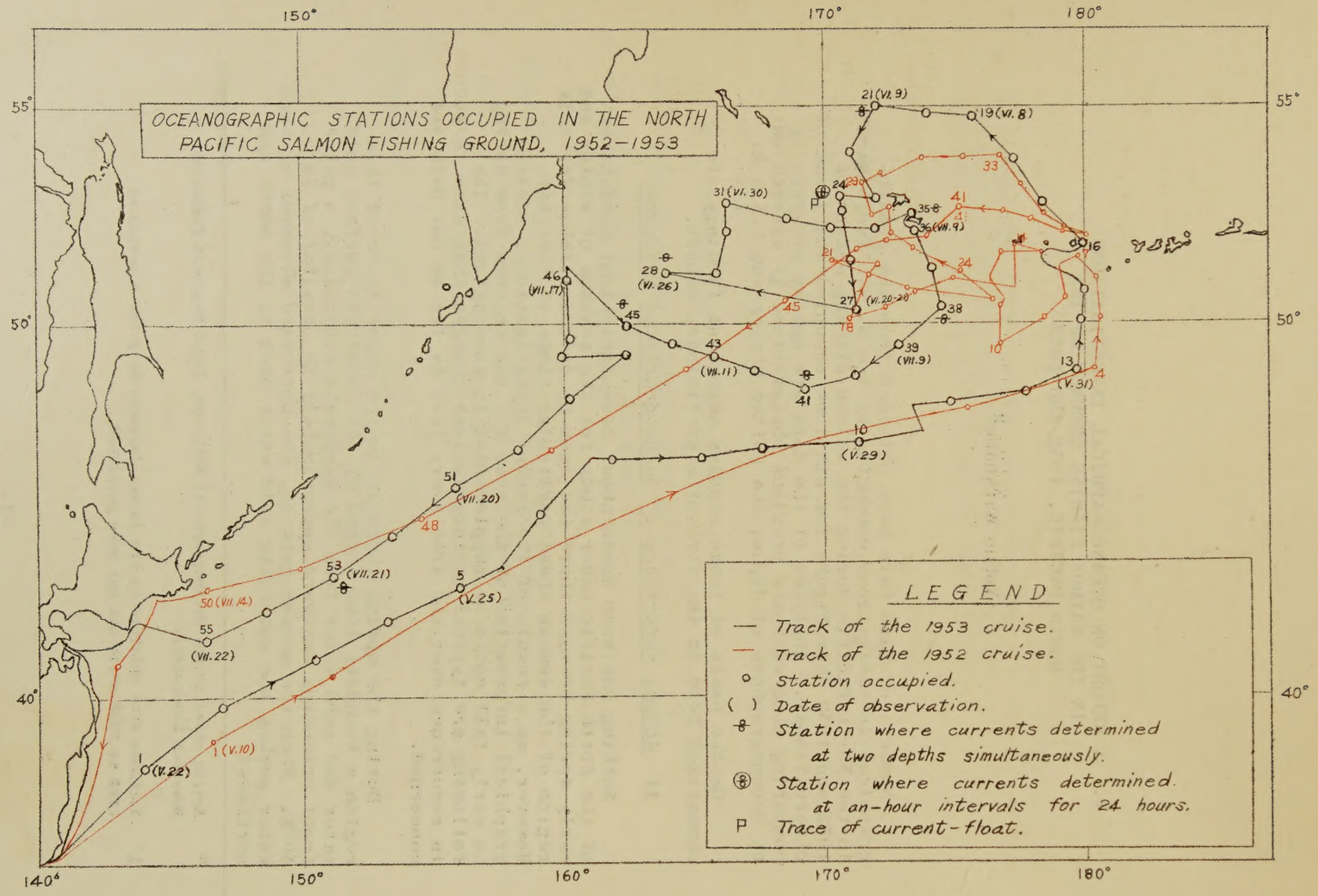
1/ Includes data obtained by the former Japanese Navy for a period of 1934 to 1936 which has not been published.


OCEANOGRAPHIC STATIONS OCCUPIED IN THE NORTH PACIFIC SALMON FISHING GROUND, 1952–1953
150°
170°
180°
55°
50°
40°
140°
160°
21(VI.9)
19(VI.8)
31(VI.30)
28 (VI.26)
46 (VII.17)
45
43 (VII.11)
41
27 (VI.20-26)
38
39 (VII.9)
13 (V.31)
10 (V.29)
51 (VII.20)
48
53 (VII.21)
50 (VII.14)
55 (VII.22)
5 (V.25)
1 (V.22)
1 (V.10)
LEGEND
Track of the 1953 cruise.
Track of the 1952 cruise.
Station occupied.
( ) Date of observation.
Station where currents determined at two depths simultaneously.
Station where currents determined at an-hour intervals for 24 hours.
Trace of current-float.

In consequence, during the latter part of spring to the early summer the polar front changes its direction to run towards the northeast. Thus, the polar front, starting from a certain area on the Pacific side of Hokkaido, develops towards the northeast along the Kurile Islands and reaches the Bering Sea through a passage between the Commanders Islands and Attu Island.

When the midsummer comes, a wedge of warm water moving westward along the southern side of the Commanders Islands gains such a strength that it exerts pressure upon the subarctic surface cold water which is remaining inside the polar front. Therefore the subarctic water in the area is pressed closely against Kamchatka coast, then finally cut in two. There the warm water is also parted into two directions. One of the branches flows into the Bering Sea through an opening between the Commanders Islands and Kamchatka Peninsula. The other is carried down southward closely along the peninsula and enters the Sea of Okhotsk through straits at the northern part of the Kurile Islands.

In the vicinity of the Kurile Islands the subarctic surface water which has been separated by the westward expansion of warm water forms the "Kurile Circulation" (named temporarily) counter-clockwise on the Pacific side of the islands. This circulation seems to account for infusion of water from the Sea of Okhotsk into the Pacific area, a cold current which is carried down along the eastern coasts of Hokkaido and Tohoku Region, and which is supposed to contribute to the development of Oyashio in summer. On the other hand, the cold water of the Bering Sea moves to the south on the upper layer closely along Kamchatka coast. The flow of this current is negligibly small, however.

In the season from fall to winter when the northward flowing warm water becomes weaker, while the southward movement of subarctic surface layer prevalent under the influence of cooling surface atmosphere, the direction of the polar front turns back gradually so as to run in parallel to longitudinal line.

2) *Warm Water Entering the Bering Sea:*

On the Pacific side of the Aleutian area west of long. 180°E. a warm water flowing westward is observed for a period of spring to summer. The current pours into the Bering Sea, turning at the west of Attu Island and is regarded as a component part of the warm water mass mentioned in Section 1.

3) *Turbulence Around the West Aleutian:*

Between the western part of the Aleutian Islands and the current flowing westward along the islands clockwise whirlpools are developing one after another, moving to the west little by little. In this cause the currents adjacent

to the islands are subjected to various changes so that the waters both on the Bering Sea and on the Pacific flow in and out through numbers of openings located between the islands. Owing to the development of the tidal current the flowing patterns inshore the islands become more complicated than they are offshore. On the north of Semisopochnoi Island the current velocity was determined to be two knots at a maximum.

4) *Quasi-Isentropic Analysis of the Waters:*

Water on the Pacific coast of the Aleutian Islands appears much similar in character to that on the Bering Sea. And this is particularly true for water under the upper layer. Mixing of warm water and cold water in this area has been studied on the basis of analysis of TS curve and isopycnal line. The result reveals that the warm water mixed in depths of 200-300 meters represents more than 60 per cent, while the cold water prevails on the surface with a mixture of about 20 per cent of the warm water.

5) *Stratification of the Waters:*

Of the stratification of sea-water in a northernmost region of the Pacific covering Aleutian, Kurile Islands, and the eastern coast of Kamchatka, the most characteristic is the existence of an intermediate cold water at depths of 75-150 meters. Suspended between the surface (0-50 meters) and the intermediate layer (75-150 meters) is a spring layer of temperature and density. The surface water may be regarded as a convection layer, since it consists of water almost uniform in character. In this region of the Pacific a major part of the intermediate cold layer is composed of water that has sunk from the surface and remained there due to the cooling effect in the previous winter. This is supposed to be one of the causes characterizing the horizontal distribution of upper layer in the summer. The advection of an abnormal water mass may be counted as another important cause.

6) *Kind of Currents in the Area:*

A distinct drift current prevails on the upper layer of 0-50 meters in the area. While, under the upper layer, a density current plays an important role in transportation of the water mass and has a close relation with the distribution of intermediate cold water and warm water flowing under this layer.

7) *Translocation of Fishing Grounds:*

The opening of salmon fishery in the North Pacific for both years fell on a season when the subarctic surface cold water was being driven back by the northward flowing warm water as described in the foregoing section. The major fishing ground was located in the vicinity of the boundary area of

these waters. When the season went on, the boundary line moved westward, following hydrographical transition. And so did the fishing ground, too. A better catch was realized in an area where horizontal gradients of temperature and chlorinity were remarkable with the presence of upwelling from the intermediate cold water.

According to Z. Nakai,* a heavy concentration of zooplankton was very often associated with an area in which the salmon were caught much more than elsewhere. Not only that, but plankton concentration was also moving west along with the rich fishing ground. He has pointed out that such a close association between quantitative distribution of plankton and hydrographical transition should be worth paying attention when one is in search of a fishing ground in this region of the Pacific.

In an area south of the Commanders Islands the fishing season would reach its height when a branch of the warm water extends westward along the islands. It is interesting to note that the fishing ground at the end of season for 1953 was found in the similar position located around the northern margine of the Kurile Circulation as it had been at that time of 1952.

8) *Annual Fluctuations in the Sea Condition:*

The oceanographical conditions in the North Pacific referred to in Section 1 tends to fluctuate from year to year. Particularly in 1953 the conditions were found considerably different from those in the same season of 1952, on which detailed study is under way. Generally speaking, temperatures of both water and air in the Aleutian area were higher this year than they had been last year so that the oceanographic conditions characteristic to the summer occurred there about two weeks earlier than they did in the previous season. On the contrary, an abnormally low temperature which was exceptional in recent years was observed in the waters off the North East District of Japan.

It may be stated in brief that oceanographical transition in this part of the North Pacific is mainly dependent upon the balance between interactive forces of warm water from the temperate zone and the subarctic surface cold water. This factor is thought to fluctuate from time to time probably under the influence of the general circulation of water in the northern hemisphere of the Pacific Ocean.

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* Special Publication No. 3-2: - A Preliminary Report on Surveys of Plankton and Salmon Stomach Contents from the North Pacific, 1952.

2. A PRELIMINARY REPORT ON SURVEYS OF PLANKTON AND SALMON STOMACH CONTENTS FROM THE NORTH PACIFIC, 1952

Zinziro Nakai* and Koji Honjo**

INTRODUCTION

The present authors have made a study on plankton and the stomach contents of salmon collected from the waters adjacent to the Aleutian Islands by the R.V. "Tenyo-Maru" (217 gross tons) of the Tokai Regional Fisheries Research Laboratory during a period from May to July 1952. The results from identification of the plankton and the stomach contents as well as their determination in wet-weight and in number will be later published on a full scale of the surveys. Here we are concerned with an outline of the study abridged from the detailed report.

Our sincere acknowledgments are due to Messrs. Nobuo Watanabe, Rinnosuke Fukai, oceanographers; Shotaro Sakai, captain, and the crew of the "Tenyo-Maru" who all made laborious efforts in collecting the samples.

MATERIALS AND METHODS

The samples of plankton for the present study were collected by vertical hauls of a 45-centimeter net with 0.33-mm. mesh from a depth of 150 meters or the bottom to the surface at about one meter per second. The samples were preserved in formalin solution on board the boat. In an early half of the period from May 17 to June 13, 16 stations were occupied for

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the collection, and 24 stations for the later part of the survey period from June 15 to July 9, at points as illustrated with circles and small Arabic numerals in Figs. 1 and 2, respectively. Included in the materials are the plankton hauled in at additional seven stations occupied in an area neighboring to those of Figs. 1 and 2.

The stomach contents were obtained from a portion of the salmon caught by drift net at four stations indicated with triangles and Roman numerals in the same figures. Of total 22 individuals of the salmon used for the stomach content analysis, two for both chum salmon *(Onchorhynchus keta)* and pink salmon *(O. gorbuscha)* were obtained at each of four stations; and two for sockeye salmon *(O. nerka)* at each of three stations. Body length of the fish ranged from 43 to 64 centimeters. After identification of the stomach contents at the laboratory, they were measured in wet-weight in accordance of species.

OUTLINE OF THE RESULTS

1) Plankton Collected by Net

A. *Specific Composition:* Since the net used for the surveys had a 0.33-mm. mesh, the sample collected by the net may be regarded as macroplankton.

The composition of important species aggregated from 47 stations are expressed in percentage on the basis of wet-weight determination as follows:

Calanus cristatus Kröyer	42.4 %	
" *plumchrus* Marukawa	29.1	
Eucalanus bungii bungii Giesbrecht	11.0	
Subtotal of Copepoda		82.5 %
Thysanoessa longipes Brant	0.7 %	
" sp.	1.1	
Euphausia pacifica Hansen	0.7	
Subtotal of Euphausiacea		2.5 %
Themisto sp.	1.0 %	
Sagitta elegans Verrill	3.4	
Others	10.6	
Total	100.0 %	

Fig. 1 — Stations Occupied for Sampling by the R.V. "Tenyo-Maru" and Distribution of Plankton Based on Settled Volume, First Half of Survey Period: May 17 — June 13, 1952

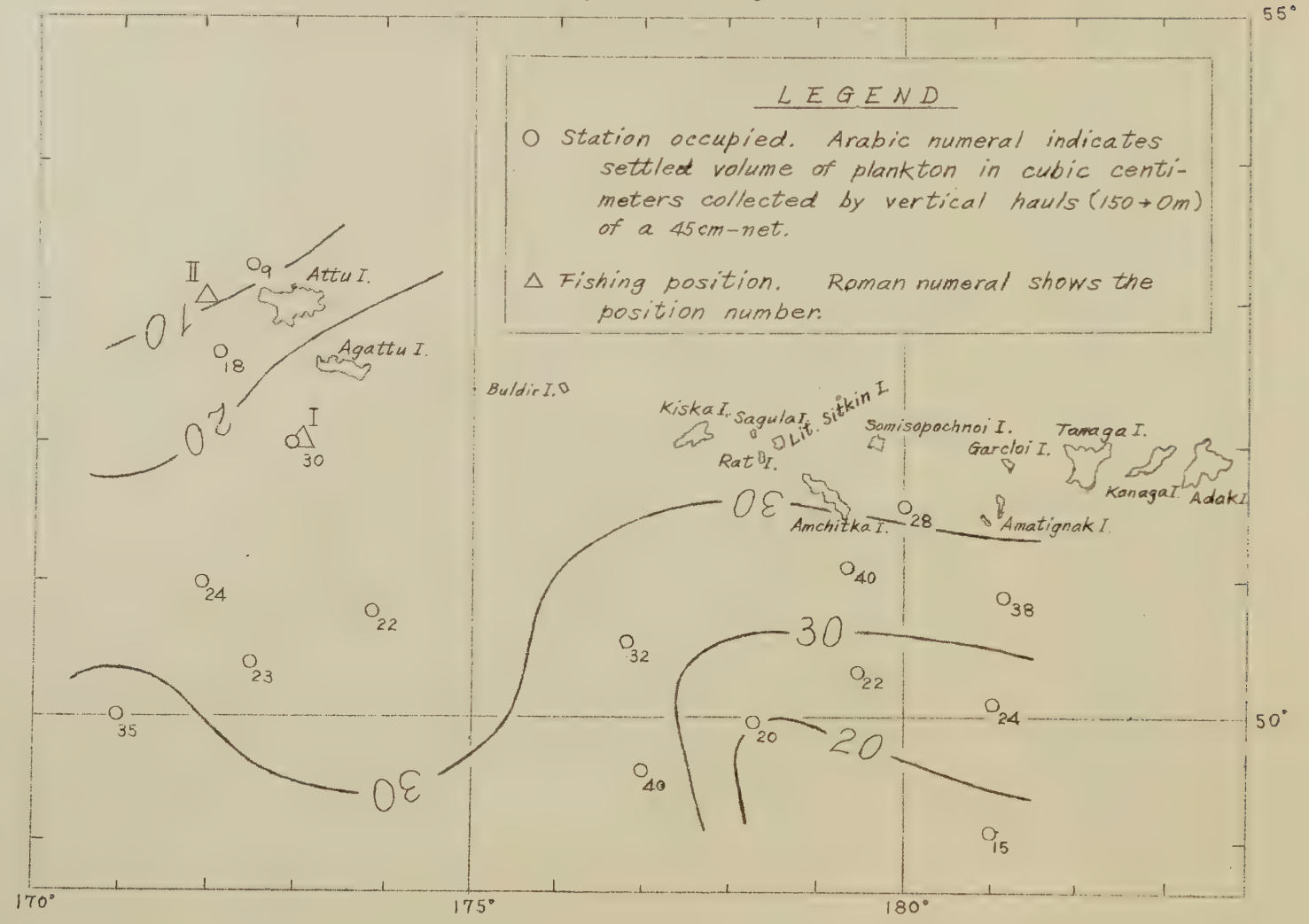
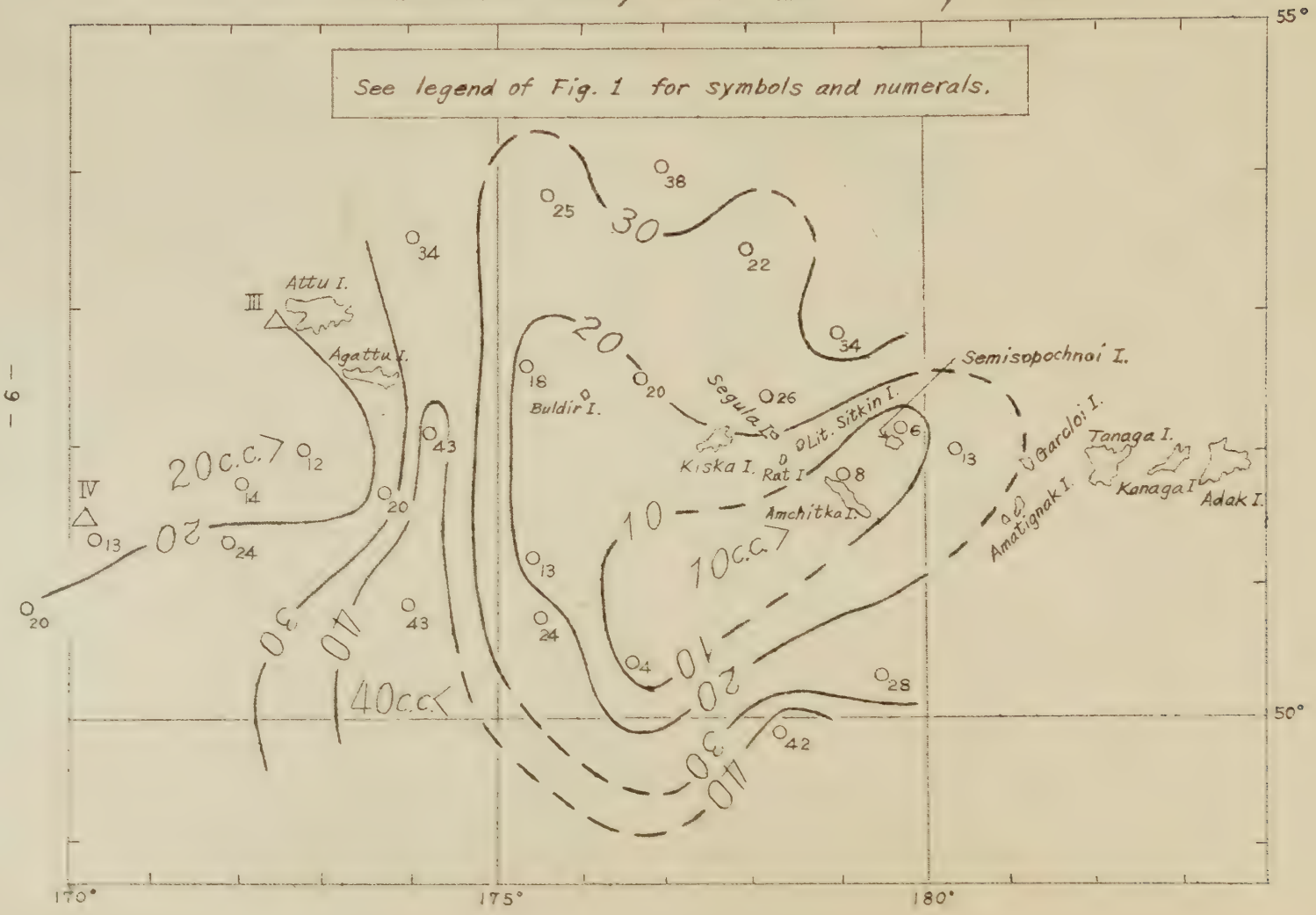


Fig. 2 — Stations Occupied for Sampling by the R. V. "Tenyo-Maru" and Distribution of Plankton Based on Settled Volume, Second Half of Survey Period: June 15 – July 9, 1952



As is obvious from the above tabulation, Copepoda represent a greater majority in wet-weight, of which *C. cristatus* and *C. plumchrus* amount to more than 70 per cent of the total catch. On the other hand, Euphausiacea including three important species remain only 2.5 per cent of the total.

However, they all are the indicator species of cold water.

B. *Quantitative Distribution:* The plankton netted from everyone of 47 stations were allowed to stand for 24 hours to determine the settled volume.1/ The following is the quantitative distribution of plankton in the area estimated on the basis of the settled volume thus obtained.

During the first half of the survey period from May to the middle of June (Fig. 1), meager concentrations of the plankton, less than 20cc. per haul, were found at different localities, one in the northwest of Agattu Island, and the other, about 100 nautical miles south of Amchitka Island. Bordering on the southern tip of Amchitka Island a remarkably dense concentration, more than 30cc. per haul, formed a strip some 60 nautical miles in width, enbracing the meager area of the south.

In the later part of the period from the middle of June to early July (Fig. 2), an area thinly populated by plankton, less than 10cc. per haul, presented in the waters adjacent to Semisopochnoi and Amchitka Islands. This area was isolated by thicker concentrations in a rough ellipse with the long diameter extending over 150 miles SSW.

The sea west of Agattu Island was populated with plankton as thinly as it had been in the first half of the period. The concentration in the area remained less than 20cc. per haul. Between those meager concentrations was a belt of dense population over 30cc. per haul which extended along 174°E. long. Particularly, a wedge of waters crowded by plankton with a concentration more than 40cc. per haul thrusted into the area up to the south of Agattu Island.

As has been described above, the distribution patterns for the earlier and later parts of the period are distinguished from each other. In the light of these observations it may be assumed that the meager population, which had occurred in an area far south of Amchitka Island in the early period, was likely carried northwestward as the season went on. As a result the thin population was isolated within a zone centering around Amchitka Island as seen in the later period. On the other hand, the densely populated water in the first period appears to have moved westwardly to the vicinity of long. 174°E.

It is worth paying attention that a greater amount of the salmon caught by the Japanese fishing fleet in the first half of the period occurred in the waters southwest of Amchitka Island where the plankton populated most densely, and the westward movement of warm water on the upper layer with low salinity which was pointed out by N. Watanabe (1952) 2/ was accompanied not only by the heavy concentration of plankton but also by rich fishing grounds. These facts would be essential in finding relationship between oceanographical conditions and standing crops of plankton, and serve as a helpful symptom for fishermen in their search of salmon fishing grounds.

2) Analysis of the Salmon Stomach Contents

Based on the result obtained from the stomach content analysis a study has been made in relation to specific composition of the food fed by salmon and the number of salmon eaten particular species of food.

It was *Thysanoessa* that outmeasured other plankton in wet-weight which were recovered from all the samples used for the current study. With the exception of *O. keta*, Copepoda came to the second place in weight. In addition to them, Pteropoda, *Themisto* and *Aglantha* were sometimes found to be an important food depending on samples. Apart from plankton, considerable amounts of squids and larval fish of Atka mackerel were recovered from some of the samples.

Individual frequency of the salmon including *O. keta*, *O. nerka* and *O. gorbuscha*, which ate a particular form of food, is expressed in percentage.

Salmon found with food		91 %
a) Salmon fed on	plankton	91 %
" "	*Thysanoessa*	78 %
" "	*Themisto*	55 %
" "	Copepoda	45 %
" "	Pteropoda	45 %
" "	*Aglantha*	13 %
b) Salmon fed on	fish	23 %
c) Salmon fed on	squids	18 %
Salmon found without food		9 %

Evidently from the above tabulation, all the samples which were found with food in their stomachs had plankton without exception. They occurred in a greater proportion than those found with fish or squids. In particular the salmon taken *Thysanoessa* as their food outnumbered the fish eaten other organisms.

3) Relationship Between the Food and Netted Plankton

As far as the present data are concerned, there is a certain discrepancy between plankton collected by net and those recovered from the stomach of salmon. For instance, Copepoda, and more specifically, *Calanus cristatus*, which occurred most abundantly in the net collection are exceeded by *Thysanoessa* in weight of the stomach contents. Whereas, the latter was caught but very few in net hauling.

The disagreement in occurrence between the standing crops and the stomach contents may be attributed to inter-relationship between the behaviors of plankton and of salmon which would have influences upon their respective distribution as well as on feeding activities of the fish. This should be regarded as an important subject that remains to be solved in the future.

1/ Volume of water strained in haulings will be adjusted in a forthcoming report.

2/ N. Watanabe. 1952: An Oceanographical Report on the North Pacific Salmon Fishing Grounds by the R.V. 'Tenyo-Maru', May-July 1952, (in Japanese).

Note: The above two papers have been translated from Japanese texts prepared by the authors for the purposed of submitting them before the North Pacific Fisheries Conference to be held between the United States, Canada and Japan at Washington D. C. in February 1954.

List of Special Publications Issued by the
Tokai Regional Fisheries Research Laboratory

No. 1 : On Fishery for "Iwashi" (Sardine, Anchovy and Round Herring) and Research of its Resources in the Japanese Waters, by Zinziro Nakai.

No. 2 : On Quantitative Distribution of Plankton Reproduced in the Northern Pacific, by Zinziro Nakai.